TECHNICAL REPORT ARCCB-TR-95027

ULTRASONIC CULVERT THICKNESS DETERMINATION

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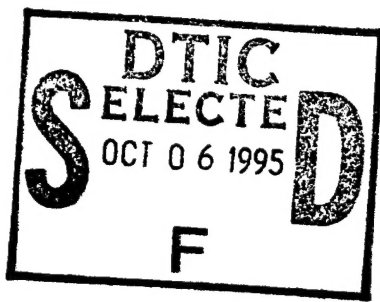
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APRIL 1995

US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
CLOSE COMBAT ARMAMENTS CENTER
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13. ABSTRACT (Maximum 200 words)

This work describes a response to the need for a practical non-destructive method of measuring the thickness of culverts in situ established at the New York State Department of Transportation. The proposed method will provide data to realistically evaluate the remaining safe lives of the culverts. The technique developed uses the ultrasonic pulse-echo technique with commercial off-the-shelf ultrasonic equipment and piezoelectric transducers in a bubbler configuration. The equipment consists of the 25DL precision thickness gage and the B120 bubbler with V316-B, 0.75-inch PTF, 20 MHz transducer--all by Panametrics. The user has to add a small water pump to provide continuous stream of water and a hollowed-out rubber stopper to ease application of the bubbler to the culvert surface.

14. SUBJECT TERMS
Ultrasonics, Squirter Technology, Bubbler Technology, Thickness Measurement, Dimensional Measurement, Time Measurement

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ACKNOWLEDGEMENTS

INTRODUCTION

In the course of their culvert evaluation, the New York State Department of Transportation (NYS DOT) expressed the need to periodically inspect culverts to determine their thickness at critical points and their ability to withstand safe further use. A method for this determination was developed and is described in this report.

Culverts allow the flow of water from one side of a highway to another. The level of water can vary somewhat. Since the culvert is made of galvanized steel, it is normally effective in withstanding corrosion for a time subject to parameters such as the quality of the zinc coating and the quality of the water passing through. The effects that these and other factors have on the culverts' life have not been firmly quantified and sometimes cannot be controlled.

THE TEST CULVERTS

We measured and examined a large culvert section and a separate strip 30 inches long by 1 inch wide. The large culvert indicates that the region of greatest vulnerability to corrosion is a band area on the inside of the culvert near the water line. Most damage accrues to the surface of the galvanized steel in that area. This is where the thickness measurements have to be performed on the inside of the culvert. The damage consists of pitting and corrosion rending the surfaces not only uneven but rough and full of pits, often resembling the rough topography of an orange rind. The surface is also covered with scale and dirt and is sometimes under water. The scale and dirt have to be knocked off and the measurements may have to be made under water. NYS DOT provided and measured the strip. Our corresponding measurements on this strip provide a test and verification for the method developed.

CHOICE OF THICKNESS MEASURING TECHNIQUE

When the thickness of a homogeneous material is determined in industry and the micrometer or other length-based instruments cannot be used, the preponderance of measurements are made with pulse-echo ultrasonics using piezoelectric transducers. The off-the-shelf electronics that go along with the transducer are most commonly called thickness gages, and the most popular, although not always useful, output is digital.

Although rarely used, electromagnetic acoustic transducers (EMATS) also have application to thickness measurements. EMATS are never indicated if piezoelectric transducers can be used because they and their associated electronics are more bulky and expensive and not off-the-shelf items. Also in this case, EMATS are less accurate than piezoelectric transducers. For thickness measurements in steel, EMATS operate at a frequency of about 2 MHz. The piezoelectric transducers we used on the present thickness measurement are 20 to 25 MHz. The thickness determination is based on the measurement of an accurate time interval obtained at its beginning and its end as the leading edge of echoes cross a threshold voltage. For higher frequencies, the rise time for the leading edge of an echo is shorter, and therefore echo amplitude jitter at higher frequencies would cause less time jitter than at lower frequencies. Higher frequencies are preferable because they cause less data scatter.

Therefore, piezoelectric transducers are preferred because they and their associated electronics are more available, less expensive, easier to use, and there is less data scatter.

PULSE-ECHO ULTRASONICS

The most common method to determine thickness is pulse-echo ultrasonics, reminiscent of sonar. In its simplest form a transducer is oil-coupled to a sample (Figure 1a), and a pulse or a spike of ultrasonic vibration is generated by the transducer and sent perpendicularly into the test piece. The same transducer is used to transmit and receive, i.e., to generate the sound and to sense the echoes. For a thin sample, the pulse width must be small enough so that the spatial extent of the pulse in the test piece is smaller than the thickness of the test piece. The sound bounces off the far or "back" wall inside this piece generating echoes picked up by the transducer and converted into voltages that are amplified and displayed on a screen in an echo train (Figure 1b). The time interval between these echoes gives the thickness of the piece if its sound velocity is known. When the thickness of thin plates is measured, a fixed delay or buffer can be used. A buffer, as understood here, is an acoustically non-attenuating medium that separates the specimen and the transducer with a time delay; its function is to allow the circuits to recover so that measurements can be made of small thicknesses. It is useful because the exciting voltage or "main bang" overwhelms the receiving circuits as well as exciting the transducer, thus making the receiver ineffective to detect small echoes for a short time following the main bang. If a buffer is used (Figures 2a and 2b), the circuits return to normal before the echo of interest arrives, and the thickness of thin plates can be measured.

The culvert surface available is difficult for thickness measurements because of its roughness even after the scale is knocked off. The basis of the ultrasonic measurement is that vibrational energy is coupled from the transducer to the material. The coupling medium is the bond. The acoustic impedance (the density times the sound velocity) of the bond should be close to that of the two media to allow energy to be transmitted. Thus, air, which has a very low acoustic impedance, does not allow the sound energy to be transmitted efficiently, whereas grease or water are better couplers or bonds. Bonding is important and discussed in this case because of the roughness of the surface, which not only makes the thickness uneven for the measurement, but also does not allow an even contact between this surface and a flat transducer. For this reason it was found that in conjunction with the technique described here, mild smoothing of the culvert face after the scale is knocked off improves the quality of the data. The smoothing can take place with a small battery-operated hand grinder. The amount of material removed is minimal.

EQUIPMENT

Transducers

Four transducer configurations with some variations were considered.

1. One element (Panametrics and Aerotech)

2. One element with solid delay (Panametrics Sonopen V260SM15)

3. Two element with delay (Panametrics D795/D793)

4. Bubbler-squirter (Panametrics Bubbler with V316-B Transducer, Krautkramer Squirter with MHT SPHFCS Transducer)

The one element oil-coupled transducer technique, previously discussed, is depicted in Figures 1a and 1b. For the actual measurement, results were poor because the trailing edge of the exciting pulse interfered with the leading edge of the first echo, in addition to the problem of nonmatching surfaces and therefore poor energy transmission. The one element with solid delay line was also not acceptable.

The best echo trains were achieved with the Krautkramer squirter-bubbler (Figure 3) and the Panametrics bubbler in order of preference. The Panametrics 25DL (described below) has automatic electrical matching for Panametrics transducers, hence the Panametrics V316-B transducer in the B120 bubbler was best with the 25DL. The bubbler has a 3/16-inch cone opening. and the transducer was 20 MHz with a 0.75-inch PTF (point target focal distance) and a 1/8-inch element diameter. Our definition of the quality of the transducers is based on which one could achieve the measurements most often. The transducer in the bubbler is focussed and transmits the sound to the specimen by means of a stream of water. The bubbler allows water to enter from the side and exit through an opening at the tip. The sound moves along the stream of water being ejected from the cone. The transducer's focal length corresponds to the distance between the transducer and the tip of the cone, so that if the tip is placed exactly on the specimen, the resolution of the bubbler is optimized. The advantage of the bubbler is that it has an easier way of coupling the sound to a small rough surface. The use of a bubbler in the culvert itself necessitates a pump and a filter that can provide water of a reasonable pressure to the bubbler. We mounted the bubbler in an appropriately hollowed-out rubber stopper to facilitate handling. positioning. and data gathering (Figure 3).

Ultrasonic Thickness Gages

In the course of this work we have identified commercially available equipment that could be utilized to develop a full inspection system for field use.

A schematic representation of such a system is given in Figure 4. A portable computer can also be used. It is connected to the ultrasonic instrumentation via an RS232 port. A small pump is used to furnish the squirter with water.

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Six different instruments were tested in our laboratory for applicability in the field environment, i.e., portability, size, power requirements, weight, and their effectiveness in generating and detecting ultrasonic signals with the preferred squirter or bubbler transducer configuration described above. Thus our efforts were directed at finding instruments capable of performing the thickness measurement with the added capability of looking at the ultrasonic signals and communicating with a portable computer through an RS232 port. These are

1. Panametrics Epoch II/IIB
2. Krautkramer USD 15
3. Krautkramer CL304
4. Panametrics 26DL Plus
5. Panametrics 5215
6. Panametrics 25DL

The first two, called digital flaw detectors by the manufacturers, have the capability of direct on-screen digital display of thickness. The "zoom" feature in these allows zooming in on the desired echo and thus gives increased capability for determining echo quality. Measurements can be memorized and the two-way RS232 communication port makes it possible to interface the units to a field-portable computer or dot matrix printer. The advantage is that the inspector can monitor the bond and thus make better judgements about the detected ultrasonic signals, which saves time and lessens confusion.

The Krautkramer CL304 is called an ultrasonic precision thickness gage with immersion and bubbler/squirter compatibility. It also has an RS232 port for computer communication and for interfacing with the Krautkramer DR1 data recorder that can store up to 7000 thickness readings. It seems quite accurate, but it is more useful in the laboratory than in the field in a wet\dry environment. This equipment has to be connected to a portable computer to memorize the data and to an oscilloscope to monitor the ultrasonic signals. We consider the CL304 unsuitable because of the need to use an external oscilloscope.

A good gage tested in view of portability is the Panametrics 26DL Plus. This is an ultrasonics thickness gage with a small oscilloscope-like display that can monitor the demodulated radio frequency (RF) ultrasonic echoes. This equipment can not be used with squirters-bubblers.

The second best instrument tested to determine thickness measurements is the Panametrics 5215 thickness gage. This gage is designed to work in various modes depending on the type of transducer used. Mode 3 is used to measure the time between successive back wall echoes following the first interface echo after the excitation pulse. This is the preferred mode when using squirters or bubblers, whereas in our case, the first interface echo can be distorted. Figure 5 represents the ultrasonic signal (on top) and the corresponding internal electronic signal used for measuring the time delay (on bottom). Thus, the measured time interval is the delay occurring between the first and the second back echo. The specimen in this case is a good steel sample 0.050 inch thick. The 5215 has several signal processing features that ensure reliable thickness measurements under a wide variety of conditions. A dual channel automatic gain control (AGC) circuit permits separate amplification of front and back surface echoes for applications in which those echoes vary widely. The measured thickness is digitally displayed and

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transferred through an RS232 port to a portable computer, and the communication software can be tailored to specific applications. Unfortunately, this is a laboratory instrument that requires an oscilloscope.

We also tested the new Panametrics 25DL ultrasonic precision thickness gage with internal data logger which combines all the desirable features in a compact package and fits our requirements. A copy of the data sheet can be found in the Appendix. This has more capabilities than the 5215 for reading thicknesses with one transducer when using a bubbler-squirter. It only weighs 1.3 pounds and has an operating time of 30 hours off its battery. It can store 5000 thickness readings and transmit them through the two-way RS232 serial port. The RF ultrasonic echo train can also be viewed on a portable computer monitor where the positions of the various gates, which are under operator control, can be seen on the screen (Figure 6). They are MTI, the Measured Time Interval; Ech Win, the Echo Window; IFBlank, the Interface Blank, which tells the system not to take any readings for the first echo after the interface for the time interval of the blank; and M3Blank, Mode 3 Blank, which tells the system not to take a time reading for the interval of this gate. The thickness obtained is printed below the wave display. The Mode 3 measurement as defined above means that the thickness measurement is made between the first and second reflections when using the buffer.

RESULTS AND DISCUSSION

Data

A pitted, rough surface often does not lend itself to thickness measurements via the application of a solid transducer to the specimen and coupling the sound energy by means of a viscous bond. In fact, one must realize that for this kind of a surface the thickness obtained is an average reflecting the method of measurement. We avoided this by making thickness measurements with a point-anvil micrometer, which gives thickness values at a point. It was found that the squirter/bubbler arrangement gave the most readings and the most satisfactory performance. It has the additional advantages of not requiring a bond since the flowing water provides the coupling and allows the measurements to be carried out under water.

Figure 7 and Table 1 give four sets of strip thickness data as a function of position. "25DL-1" and "25DL-2" are average thickness readings for each position on the strip taken by two different investigators using ultrasonics with the recommended system. "D.O.T" is the average thickness provided by the DOT obtained with a ball micrometer. "Mechanical" is thickness data taken by us with the point-anvil micrometer. This consists of two parts: the first is the "x" which represents the average for each strip, and the vertical lines associated with each strip position represent the range of values obtained with three-point anvil micrometer measurements. For the mechanical and ultrasonic measurements, the strip was divided into an equally-spaced grid such that each strip length position had three width positions associated with it. We have found that minor smoothing of the exposed surface improves the ability of the system to obtain data. The reliability of the method we used and the negligible effect of the minor smoothing of the surface can be seen by the data comparisons. Several observations can be made. It is evident from our mechanical measurements on the strip that the thickness range across one strip position is considerable for positions where much material erosion took place.

This points to the actual specimen thickness variation at each position as the main cause of the data scatter even with the grid arrangement. The mechanical strip thickness data obtained indicate that the maximum thickness variation occurs where maximum erosion took place (Figure 8). All but one of our average data sets for each strip position are within 0.005 inch of each other. The scatter is mostly within 0.002 inch for average strip thickness of 0.050 inch or greater.

Precision

By the least count, precision, or resolution of the instrument we mean the smallest change in thickness that the gage can differentiate. This is 0.0001 inch for the 25DL. The accuracy of the measurement refers to the results obtained when the same spot is measured again and again--in our case by removing the transducer between successive measurements, so that the measuring electronics of the gage can be reset each time. This results in obtaining a standard deviation, s.d., from the central value of a set. The s.d. is the root mean square (r.m.s.) value of the deviation or:

$$s.d. = \sqrt{\frac{\sum_{1}^{n} |x - <x>|^2}{n}}$$

Here $<x>$ represents the average value and n is the number of readings. Since n is the denominator, the more readings that are obtained, the smaller the value of the standard deviation. The value of the measurement then is given as $<x> \pm$ s.d. We can say that the s.d. is the accuracy to which the measurement is known. In our case this is better than 0.001 inch for regions where good data can be determined with the gage.

Measurement of the culvert thickness for the test strip we received showed that the thickness variation across one strip position was much greater than the accuracy of the measurement, so whenever the thickness at one position is given, the gage's accuracy introduces an insignificant error compared to the thickness variation.

Equipment

At first we found that by using a Krautkramer focussed transducer and squirter-bubbler to couple the ultrasonic pulses from the transducer to the specimen by a contained stream of water and the rubber stopper arrangement (Figure 3) and by using a Panametrics 5215 multiplexed thickness gage, we were able to get thickness determinations more conveniently and more frequently than with any other combination of transducers or gages. The squirter was able to couple the sound energy better over a small area, and the Panametrics gage was able to deliver echo-to-echo thickness measurements following an interface echo. Its lack of portability has just now been remedied by Panametrics. A 25DL precision thickness gage with internal datalogger provides similar measurements but with some advantages. This gage, in addition to its small size, light weight, and battery operation, can store up to 5000 data points and convey them to a computer via an RS232 port. The resolution or least count or accuracy of the instrument is 0.0001 inch. An advantage of this gage is that when it provides a visual display of the ultrasonic echo train on a portable computer, the position of the gates are clearly visible on the computer

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screen. Therefore, when the operator is not sure of the digital output of the gage, the echo train and the position of the gates can be observed from the computer screen. In this way the quality of the data can also be evaluated. The echo train can also be stored in the portable computer for later evaluation by an expert.

For a nine-foot high culvert, assuming that the water level is three to four feet high, it is possible for the technician to protect the gage from getting wet with transparent plastic. Also, the gage and the transducer-squirter can be attached to the technician's jacket, thus freeing his/her hands to work. The technician can have tools to remove the scale and dirt from the culvert, make it smooth, and then take and store the measurements, mark the spot measured, and move on. In taking the measurement, the Panametrics gage provides an RS232 port to a portable computer. The portable computer can be attached by a strap around the technician's neck making the screen visible during the work. This allows the technician to evaluate the coupling because the computer's oscilloscope-like screen presents the echo train. Each measurement is recorded and can be stored and plotted by computer according to location or to a prearranged code. Thus after each measurement series, a computer record and a hard copy exist of the data.

RECOMMENDATIONS

1. If possible, measurements should be made at the lowest water level in the culvert so that they can be performed above water. However, the measurements can also be made under water.

2. Dirt and scale should be removed from the culvert surface. The surface should also be mildly smoothed if necessary.

3. We recommend the Panametrics 25DL (see Appendix for the Data Sheet). It weighs 1.3 pounds, can be hung around the technician's neck, and can be made waterproof.

4. With the above gage, we recommend the Panametrics B120 bubbler with the V316-B, 20/0.125, F=0.75 PTF transducer.

5. A portable computer used in conjunction with the 25DL and the appropriate software allows the display and storage of the echo train, as well as storing and displaying data. This can also be enclosed in a plastic transparent waterproof container.

6.   Each point measured should be numbered and if possible assigned a realistic location on the culvert. For example, a set of measuring tapes can be fastened at recorded positions one foot apart at one end of the culvert, run across to the other side, and fastened again at the same height with respect to the culvert. In this way a grid is formed and any measurements can be referred to it. Underwater positions can also be determined with some modifications. The thickness values can be plotted on a grid and made available as a hard copy or a computer display. If necessary, the data for each point can be stored, recalled, and compared at a later date for a future inspection.

7.   A rubber stopper can be machined as indicated above so that the bubbler fits inside to facilitate the actual measurements. A magnetic ring can be incorporated at the bottom of the stopper so that the transducer can be attached to the side of the culvert for the convenience of the technician.

8.   The readings be taken with the gage as long as it gives steady readings to the accuracy desired. If, however, the technician has doubts about the reading, the position of the MTI gate can be observed from the computer. If necessary, the IFBlank or the M3Blank can be adjusted.

9.   A software routine should be developed so that once the ultrasonic echo train is stored, the gates can move, and the measurements can be made. This would be useful when a higher level expert examines the stored data at a later time to extract thickness information. The software routine could also be used to provide a colored hard copy of the data in plotted form (Figure 9).

10.   NYS DOT should consider having Benét Laboratories provide a "turn key" system that would include the computer and equipment discussed above and "in- the-field" training of personnel.

TABLE 1. METAL LOSS PROFILE PROVIDED BY THREE DIFFERENT MEASUREMENT TECHNIQUES

| Location [inches]	Ultrasonics [Inches]			Mechanical [inches]			D.O.T. Measurements	
	Avg	Variation	% Metal Loss	Avg	Variation	% Metal Loss	Avg	% Metal L
1	0.101	0.000	3	0.101	0.000	3	0.101	3
2	0.102	0.000	2	0.101	0.000	3	0.102	2
3	0.102	0.001	2	0.102	0.001	2	0.102	2
4	0.102	0.000	2	0.101	0.001	3	0.102	2
5	0.102	0.000	2	0.101	0.000	3	0.102	2
6	0.102	0.000	2	0.102	0.000	2	0.102	2
7	0.102	0.000	2	0.102	0.001	2	0.102	2
8	0.102	0.000	2	0.102	0.001	2	0.102	2
9	0.102	0.001	2	0.103	0.000	1	0.102	2
10	0.100	0.000	3	0.101	0.001	2	0.101	3
11	0.099	0.000	5	0.098	0.002	6	0.099	5
12	0.085	0.002	18	0.082	0.004	21	0.087	16
13	0.080	0.002	23	0.080	0.001	23	0.082	21
14	0.059	0.002	44	0.059	0.003	43	0.058	44
15	0.050	0.001	52	0.048	0.002	54	0.048	54
16	0.035	0.001	67	0.026	0.007	75	0.026	75
17	0.032	0.003	70	0.031	0.004	71	0.027	74
18	0.034	0.008	68	0.030	0.009	71	0.028	73
19	0.023	N/A	78	0.023	0.007	78	0.022	79
20	0.024	0.000	77	0.027	0.014	74	0.028	73
21	0.017	0.006	84	0.021	0.005	79	0.019	82
22	0.023	0.005	78	0.025	0.006	76	0.021	80
23	0.020	0.003	81	0.020	0.005	81	0.019	82
24	0.024	N/A	77	0.020	0.001	81	0.021	80
25	0.031	0.001	71	0.026	0.003	75	0.028	73
26	0.043	0.004	59	0.042	0.002	60	0.044	58
27	0.050	0.002	52	0.051	0.003	51	0.05	52
28	0.037	0.002	65	0.043	0.007	58	0.043	59
29	0.042	0.013	59	0.042	0.005	59	0.03	71
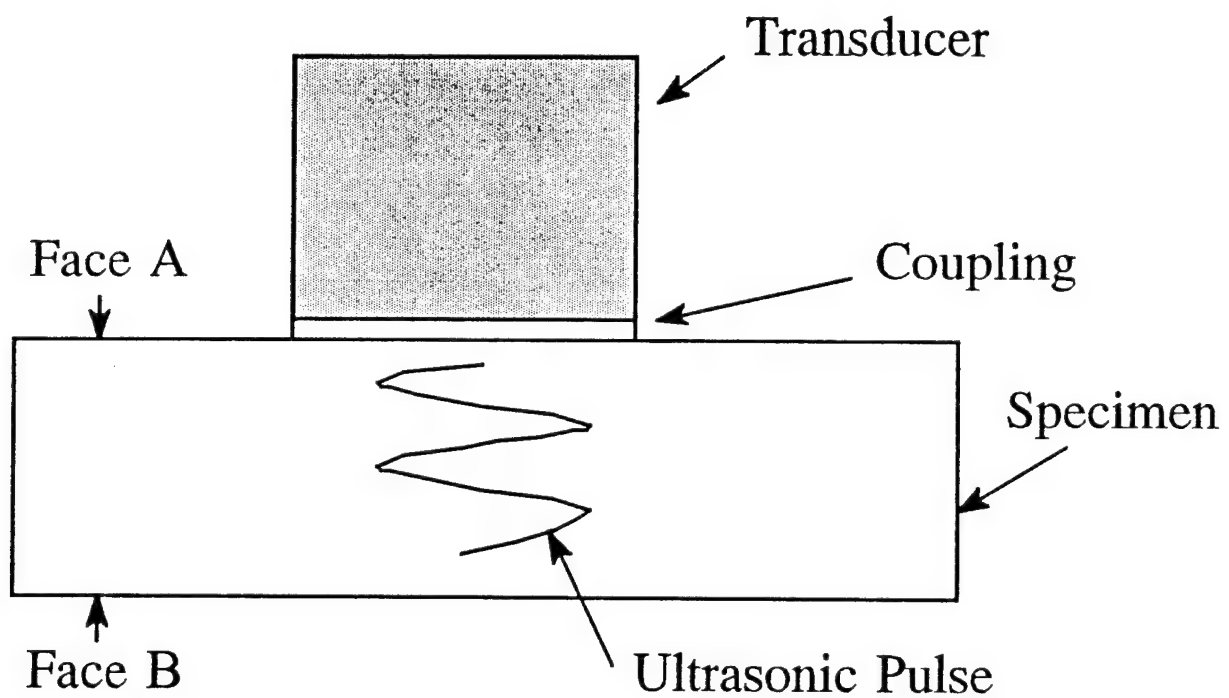
Figure 1A Single transducer arrangement for pulse-echo ultrasonic
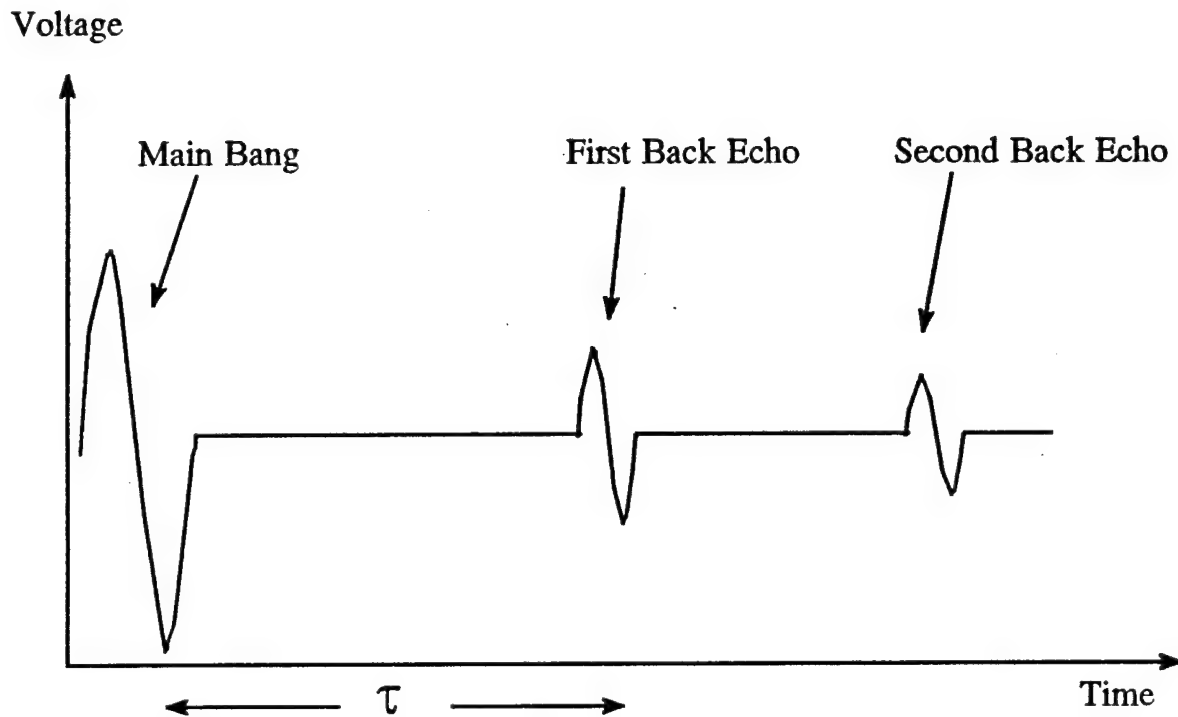measurements of thickness.

Figure 1B Typical echo train resulting from an arrangement as depicted in Fig 1A. τ is the time for round trip travel of the ultrasonic pulse between face A and face B.
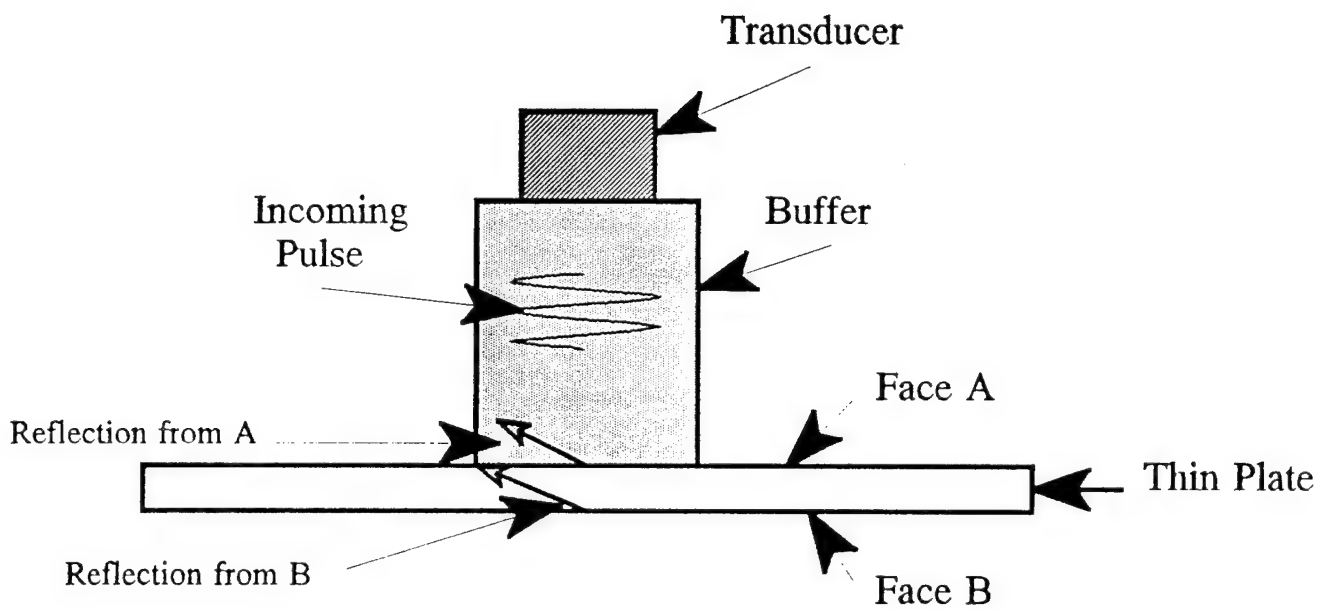
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Figure 2A Arrangement for thickness measurement of thin plate using a buffer. This allows reflections from face A and B to be distinct and measurable when they reach the transducer.
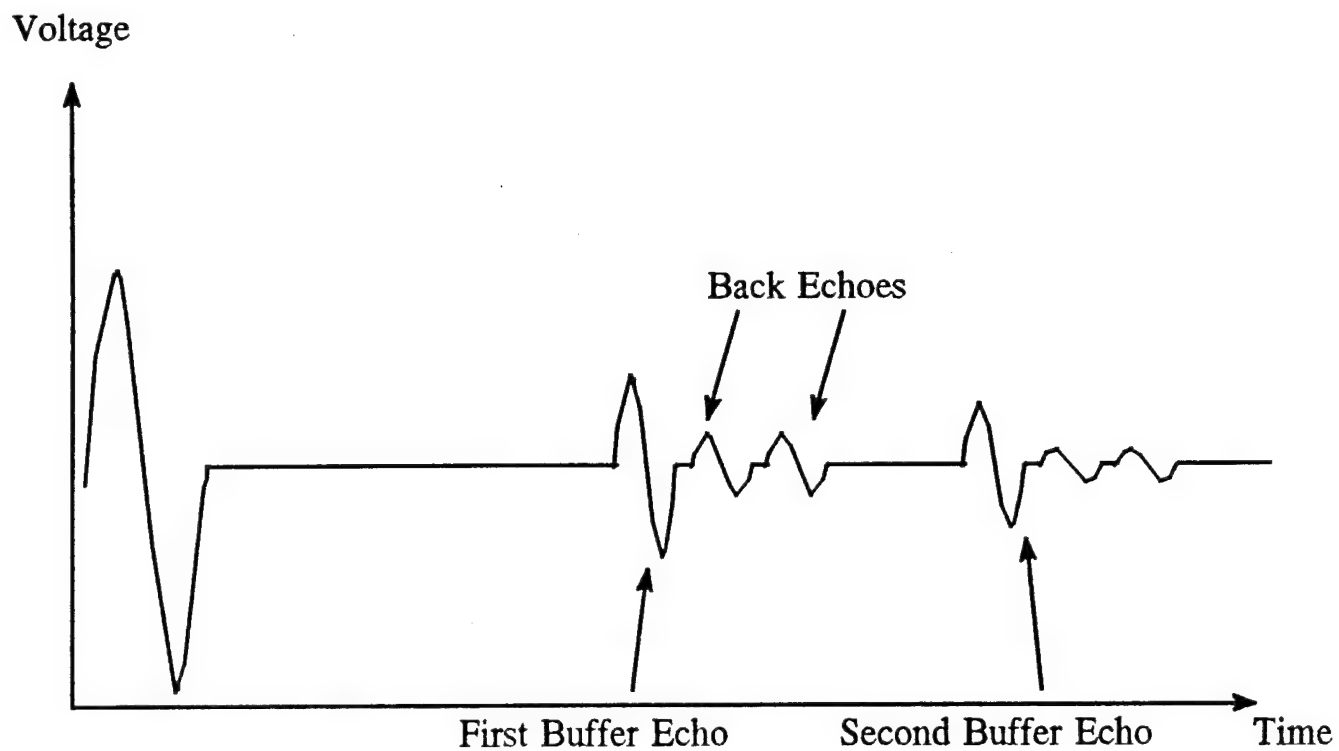
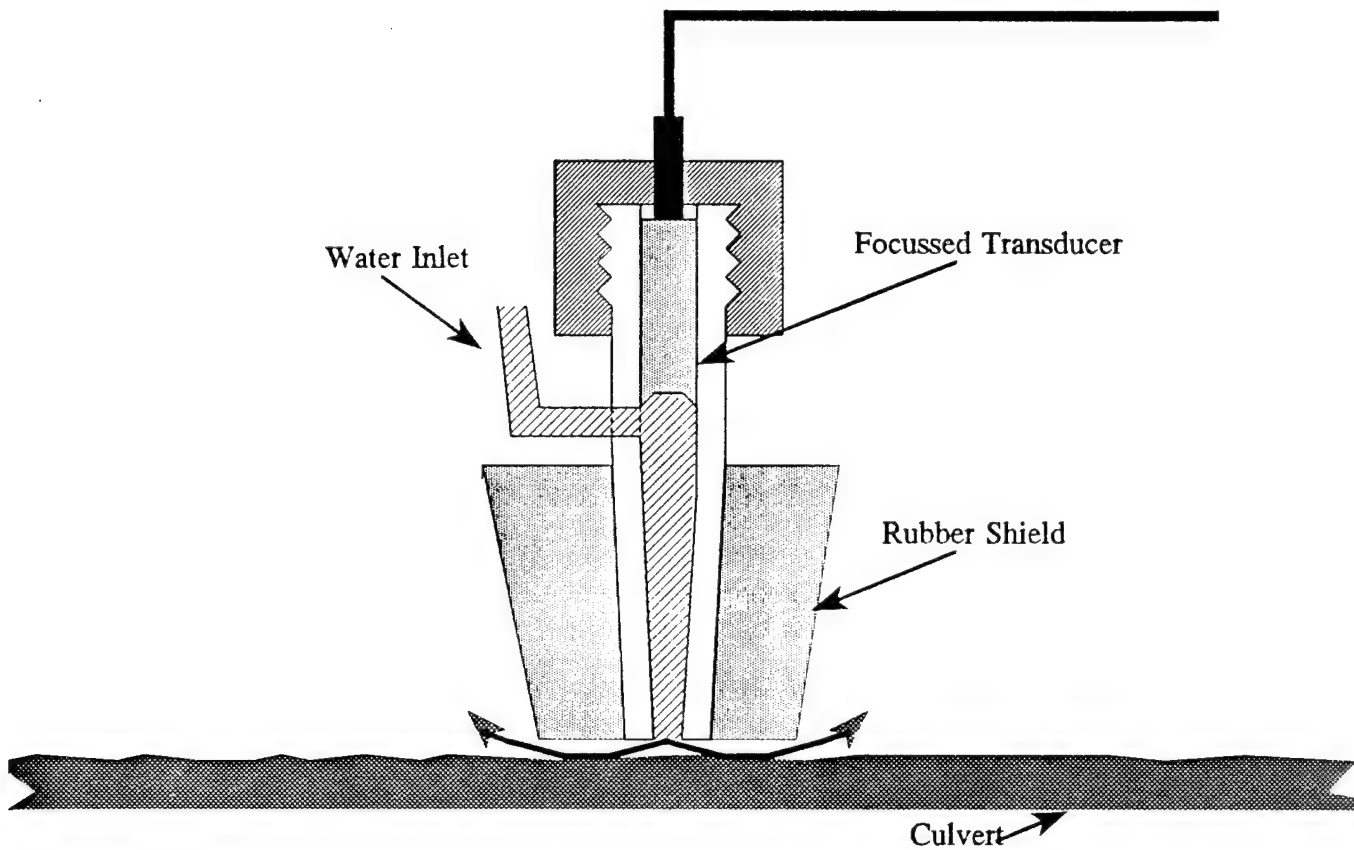Figure 2B Echo train for a buffer system for measuring thin plates.

Figure 3   Schematic representation of the Krautkramer
squirter modified in order to obtain the most useable
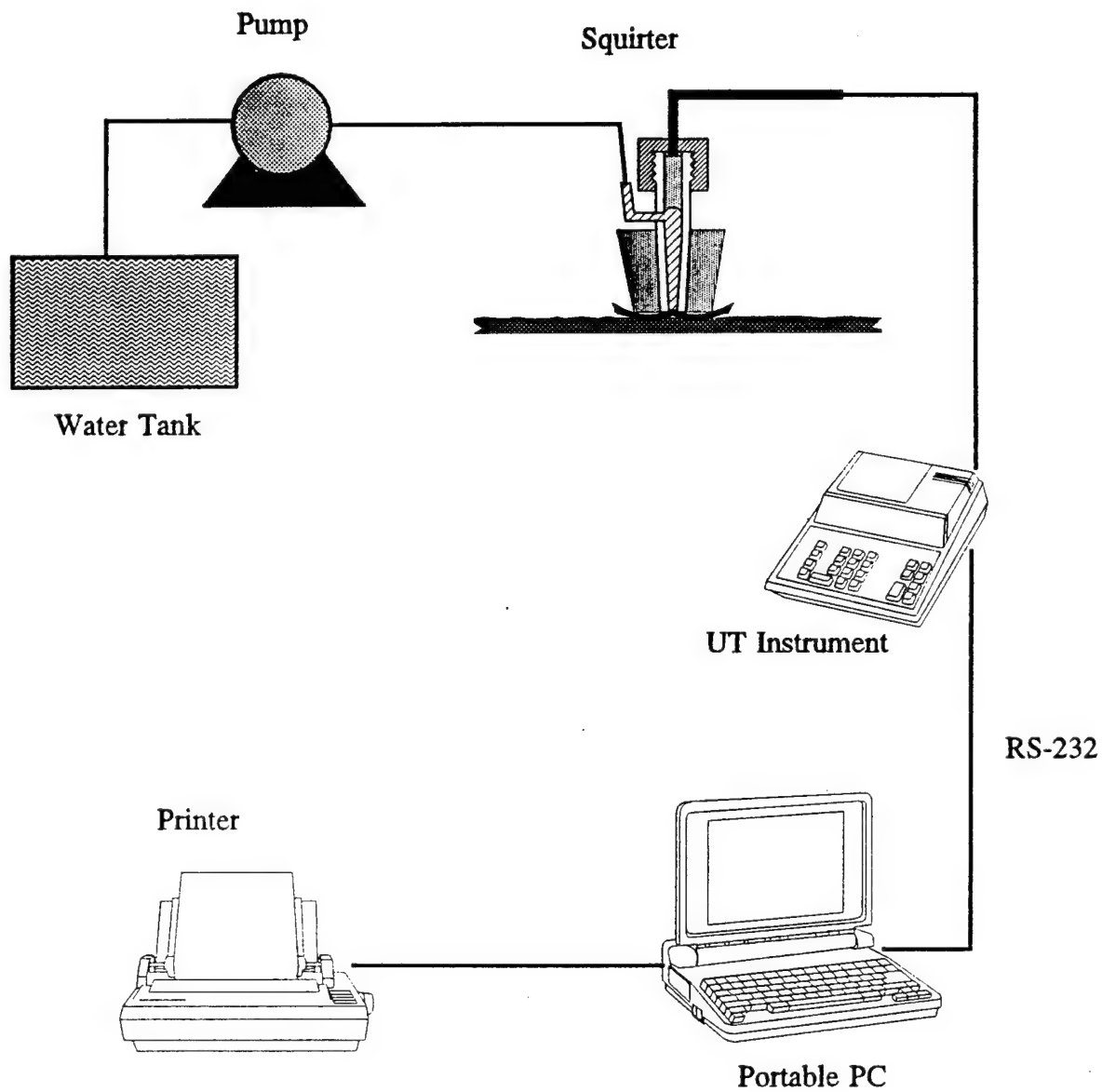ultrasonic signals for thickness determination of culverts.

Figure 4.   Schematic diagram of the proposed system for culvert thickness determination.
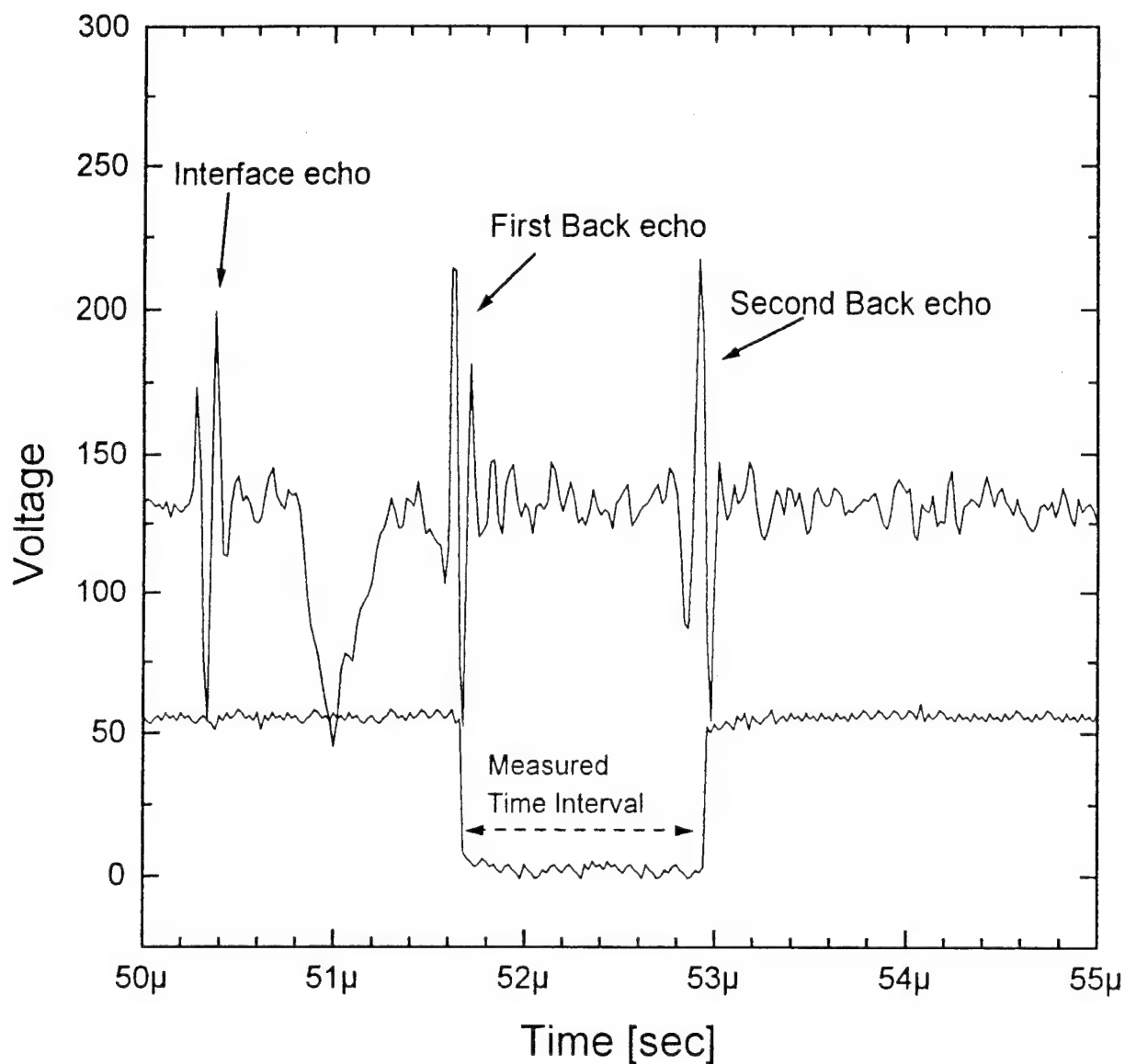
Figure 5. Actual data from a Panametrics 5215 thickness gage on a good plate 0.050 inch thick. The Krautkramer squirter was used. The oscilloscope display of the echo train, which resembles Fig. 2b, is given at the top. The AGC causes the back echoes to be as large as the interface echo. The bottom curve shows how the instrument processes and evaluates the top curve.

PCSCOPE

RECALL

MODE

_____

MTI

Ech Win

IFBlank

M3Blank

AVAILABLE
USER KEYS

↑ ↓ Arrows
Horizontal
Span.

← → Arrows
Horizontal
Delay.

F3 key
Save Setup
& Waveform.

F4 key
Switch to
Collect mode

F5 key
Print Info.

F6 key
Zoom to Echo

Esc key
To exit.
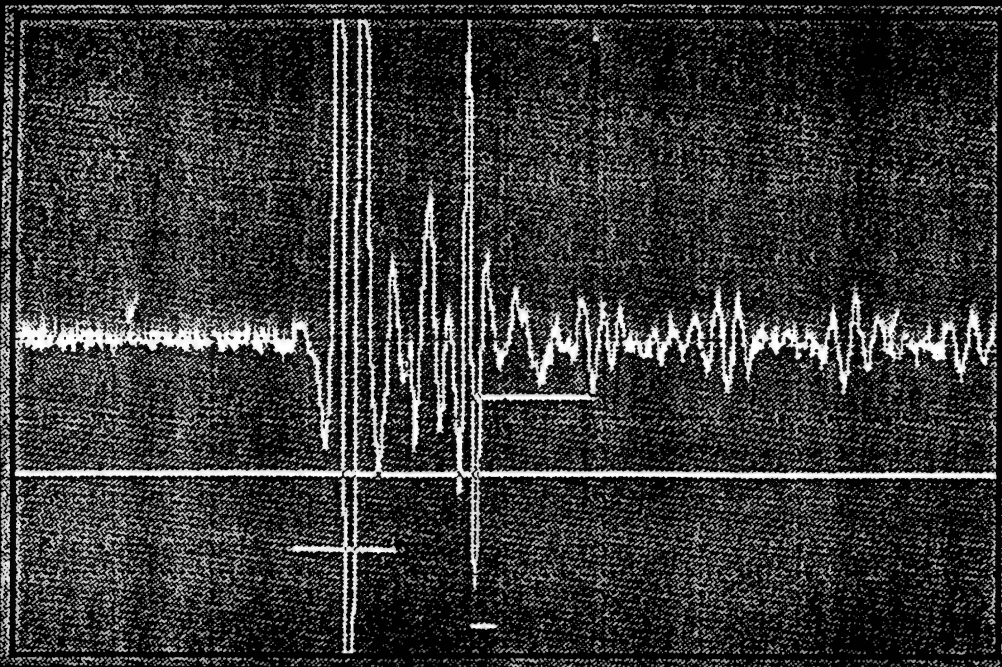
DELAY :   SCALE :
        Thickness :

        ACTIVE SETUP :

ProbeType   InitGain   Ech2Dtect
MatU   MBBlnk   IFBlnk
Zero   EchWin   M3EchBlnk
PulsePwr   DtectMode   TDGSlpe
MaxGain   Ech1Dtect

Figure 6. Display on PC screen for a culvert thickness measurement
using the Panametrics 25DL.

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Comparison of Measurements
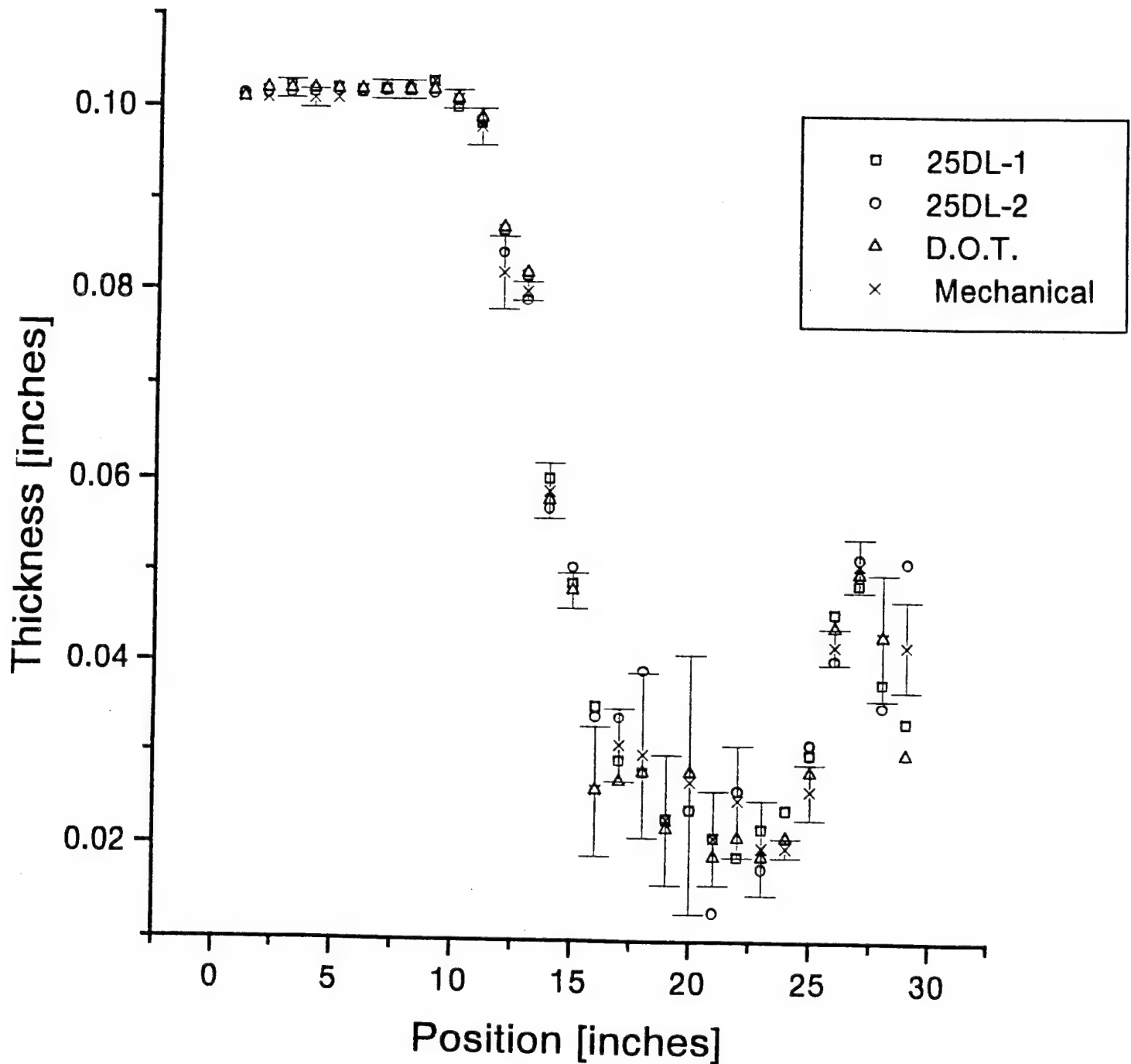
Figure 7. Thickness measurements on a culvert strip provided by the NYS DOT.
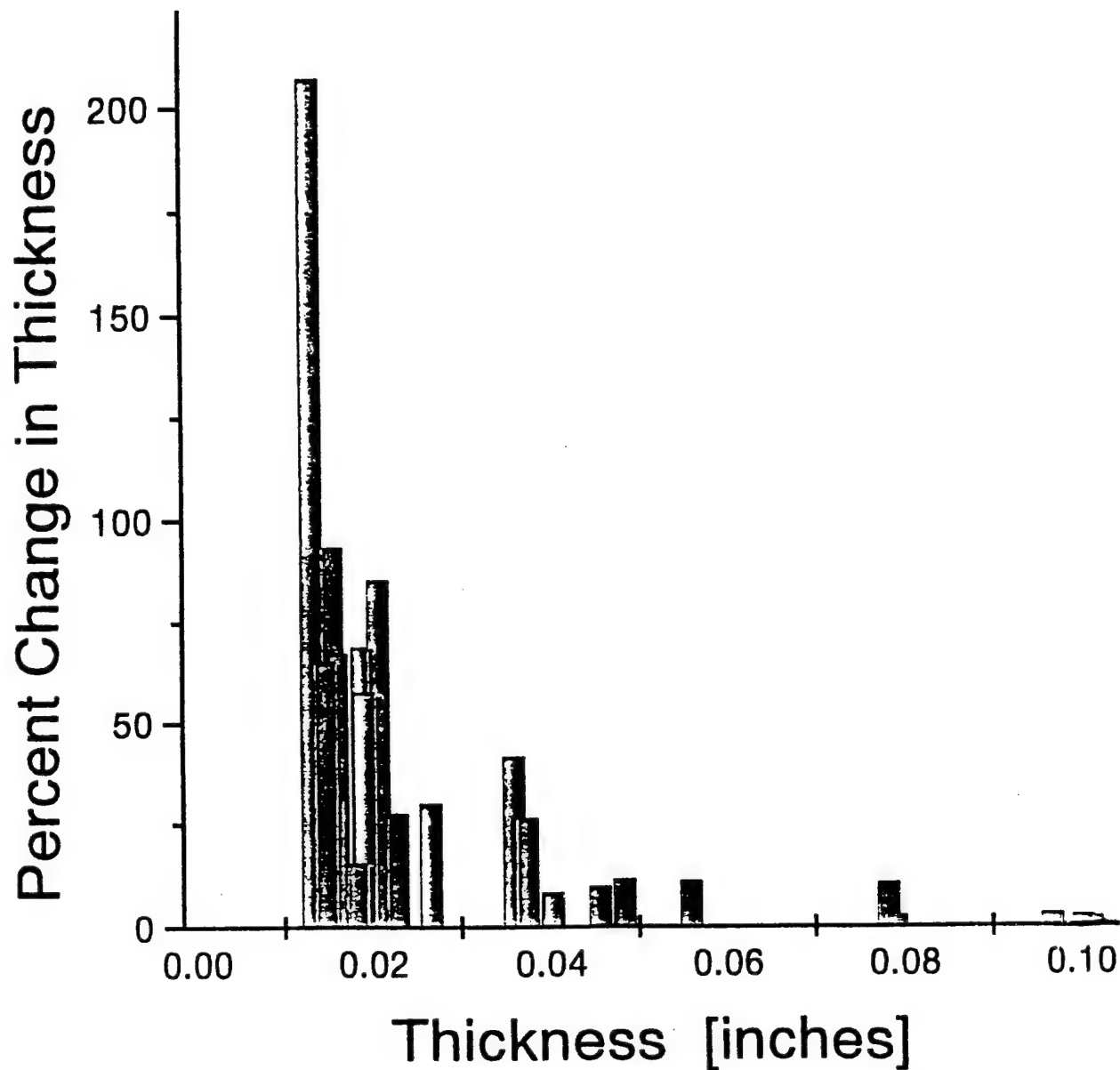
Figure 8. Relationship between percent change in thickness as a function of the average thickness measured on the culvert strip.
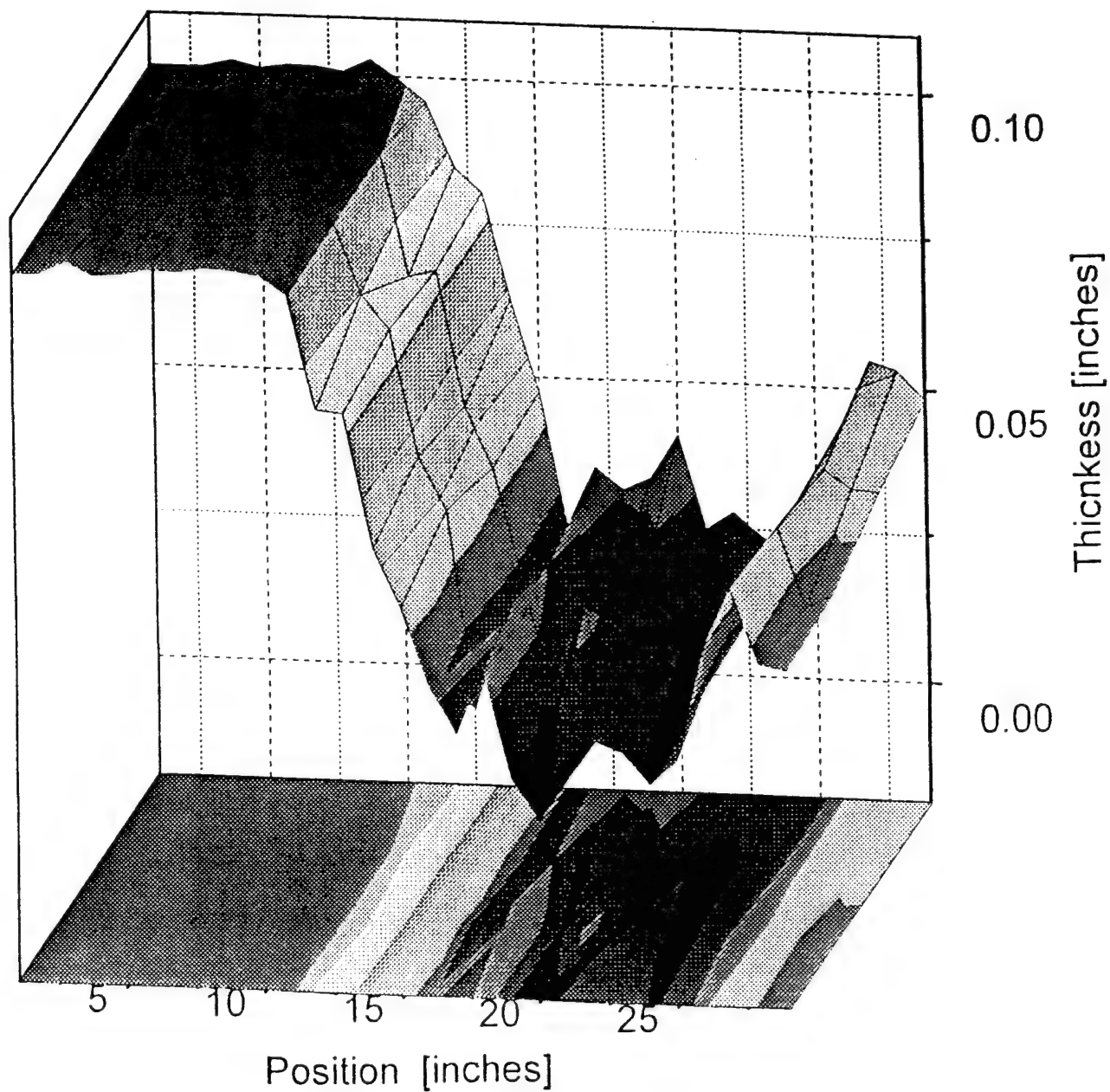
Figure 9 3-Dimensional plot of culvert thickness vs. position for the 3 by 30 point grid described in text.

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APPENDIX

Data sheet for the Panametrics 25DL

25DL Multi-Mode Ultrasonic Thickness Gage with Internal Datalogger

PANAMETRICS

25DL

Thickness Measurements with Precision, Reliability, and Simplicity

The 25DL is an ultrasonic precision thickness gage designed with one basic goal in mind — simplicity of operation regardless of the complexity of your applications.

The Model 25DL utilizes ultrasound to make accurate thickness measurements on most materials including steel, plastic, rubber, glass, and composites in just seconds. This easy-to-use handheld gage provides instant digital readings on a large backlit LCD. An internal datalogger stores over 5000 thickness readings with alphanumeric identification codes which later can be uploaded to a computer or directly sent to a printer.

- ▶ Easy to use
- ▶ Uses contact, delay line, and immersion transducers
- ▶ Application Auto-Recall with Stored Standard and Custom Setups
- ▶ Wide thickness range
- ▶ Measures most materials
- ▶ Resolution up to 0.0001" (0.001mm)
- ▶ Handheld
- ▶ Large backlit display
- ▶ Alarm functions
- ▶ Long battery life
- ▶ Inches/mm
- ▶ Alphanumeric datalogger
- ▶ Multiple on-screen languages
- ▶ Computer Interface
- ▶ Two year warranty

No other gage has more capabilities!
Unmatched thickness measurement range. Precision. Advanced features. Fast documentation. And above all, easy operation.

PANAMETRICS

MODEL 25DL ULTRASONIC THICKNESS GAGE

The Panametrics Advantage

Quality takes priority at Panametrics. When you purchase a Panametrics thickness gage, you'll also receive the advantage of more than thirty years of experience in manufacturing ultrasonic testing equipment of outstanding workmanship. We are continuously on the forefront of ultrasonic technology, introducing innovative solutions. The 25DL is the latest example of Panametrics' commitment to bring you state-of-the-art products.

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The 25DL is an All-In-One Solution for a Wide Range of Thickness Gaging Applications

Multi-measurement modes using contact, delay line, and immersion transducers enable the 25DL to be the ideal solution for almost any thickness measurement application problem:

|	
Metal:	Coils, Containers, Plates, Machined Parts, Cast Parts, Turbine Blades, Cylinder Bores, Tubing
Plastic:	Bottles, Containers, Drums, Hot Plastics, Pipes, Tubes, Preforms, Sheets
Glass:	Bottles, Bulbs, Tubes
Rubber:	Sheets, Tubes, Belts, Tires
Fiberglass:	Boat Hulls, Storage Tanks, Pipes
Composites:	Panels, Radomes, Structures

## Worldwide Applications Assistance

Panametrics offers free application evaluation and fast customer service around the globe. Send a sample of your material to our extensive testing lab at Panametrics' headquarters in Waltham, MA or to one of our many sister companies and sales agents worldwide so that we can recommend a cost-effective solution to your application problem.
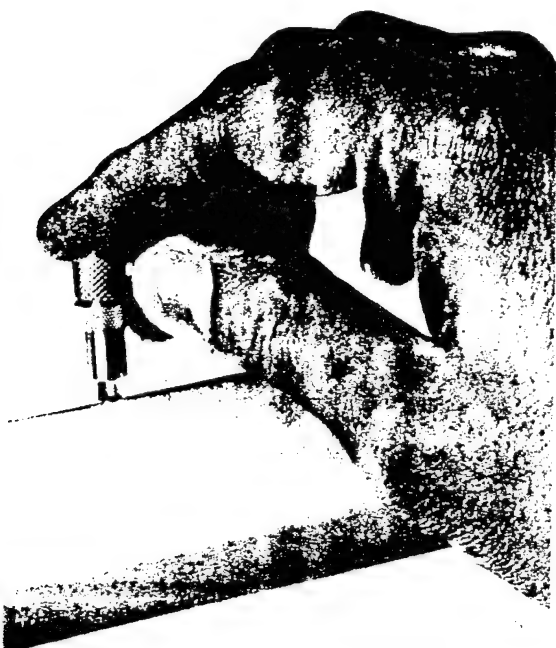
The Ultrasonic Advantage

Ultrasonic thickness measurements are accurate, reliable, repeatable, and most importantly, nondestructive. With the 25DL you achieve instant digital measurements by transmitting sound into the test part from only one side, making it unnecessary to cut or section parts. Save material, time, and labor in applications where the opposite side is difficult or impossible to access.
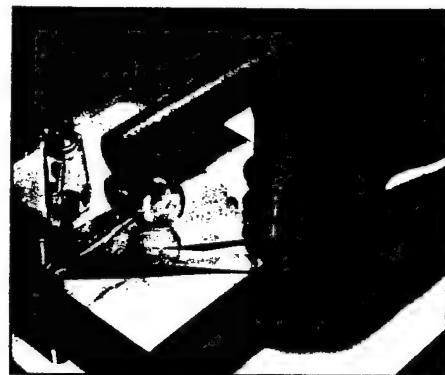
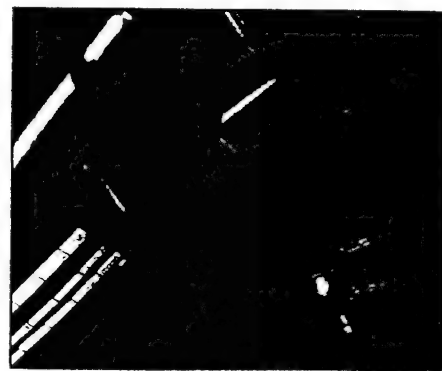**Thin Material/High Resolution**

The 25DL measures thin steel down to 0.006" (0.15mm) or plastic as thin as 0.003" (0.08mm).

General Purpose

The 25DL measures materials such as steel up to 20" (500mm) and even rubber, fiberglass, and castings.

Special Applications

The 25DL measures in areas that are sharply curved or hard to reach using the Sonopen' or immersion transducers.

✓ Application Auto-Recall Simplifies Gaging!

The 25DL's unique feature, Application Auto-Recall, simplifies making thickness measurements whether you have one or multiple applications. Select any of the listed standard transducers and the 25DL recalls all relevant internal parameters.

✓ Stored Standard Setups

The standard transducers enable you to measure the thickness of most product materials, from very thin plastics to thick steel. A benefit of the 25DL is that all Standard Setups for these transducers are already stored in the gage's memory. For easy, fast, and reliable thickness measurements, simply recall one of the Standard Setups.

✓ Stored Custom Setups

Just in case your application problem cannot be solved with one of the Standard Setups, the 25DL's versatility is enhanced by its capability to create, store, and recall 16 Custom Setups.

Transducer Part Number	Frequency MHz	Transducer Element Dia.	

Contact Transducers:

M116	20	0.125"	3mm
M112	10	0.25"	6mm
M1016	10	0.125"	3mm
M110	5.0	0.25"	6mm
M109	5.0	0.50"	13mm
M106	2.25	0.50"	13mm
M1051	2.25	0.25"	6mm

Delay Line Transducers:

M208	20	0.125"	3mm
V260	15	0.125"	3mm
M202	10	0.25"	6mm
M206	5.0	0.50"	13mm
M207	2.25	0.50"	13mm

The versatile 25DL can be used with a variety of in-stock standard contact, delay line, and immersion transducers. Most applications only require one of the standard ultrasonic transducers listed above. In addition, Panametrics has available hundreds of special transducers.

Transducers, Bubblers, and Test Blocks

With a 30MHz transducer, the V213, you'll measure as thin as 0.003" (0.08mm) in plastics and 0.006" (0.15mm) in steel.
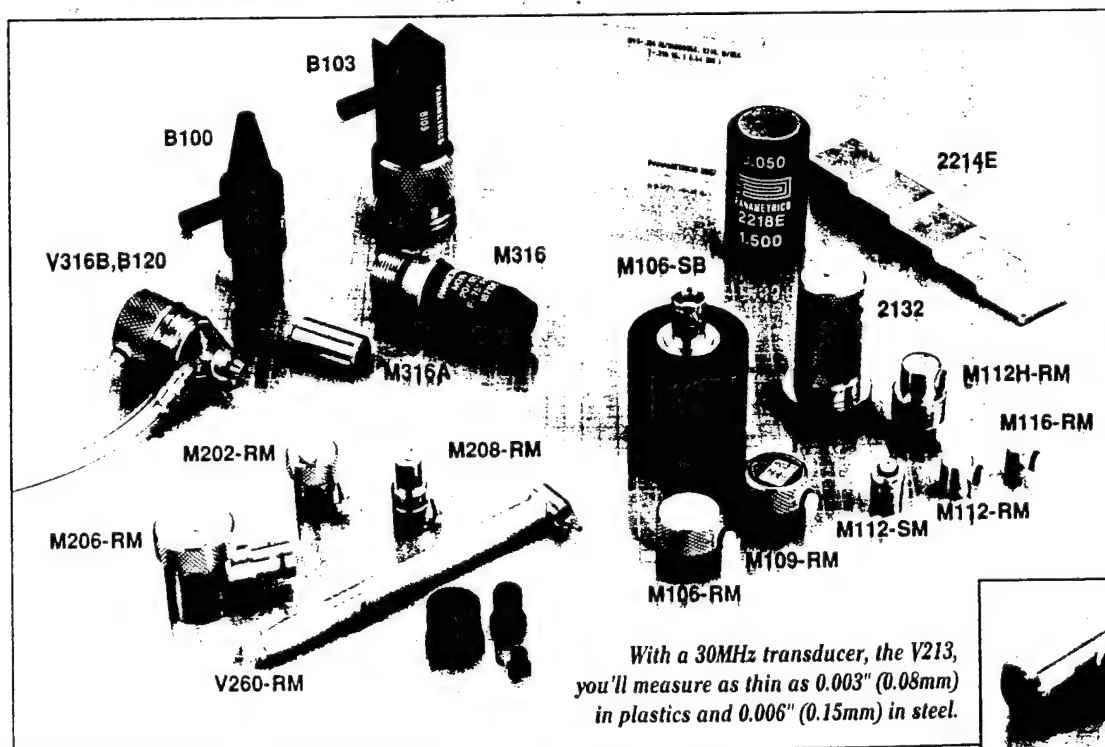
Extensive Data Collection for Fast and Reliable Documentation

✓ Internal Datalogger

The 25DL's extensive internal datalogger allows you to store, recall, and transmit over 5000 thickness readings along with Identification Codes. To store data, simply press the SAVE key. The 25DL's datalogging capabilities save time by eliminating the need for manual data recording. All stored information can be transmitted from the 25DL to a computer or printer for statistical analysis.

✓ Alphanumeric Identification Codes

You can assign up to 10 alphanumeric characters to each stored thickness measurement. Each thickness reading is fully documented with parameter information such as material sound velocity, transducer data, and measurement mode.

On-board Statistics Calculator

The Statistics Calculator is useful in situations when you don't have access to a computer but still want to see your thickness data with statistical output. You can use the 25DL's internal datalogging functions to generate reports that can be transmitted directly to your printer.

✓ PC Scope

The innovative 25DL PC Scope feature allows you to instantly display the live ultrasonic waveform with gates and thickness readings directly on your computer screen. This is ideal for difficult applications or when setup parameters need closer examination.
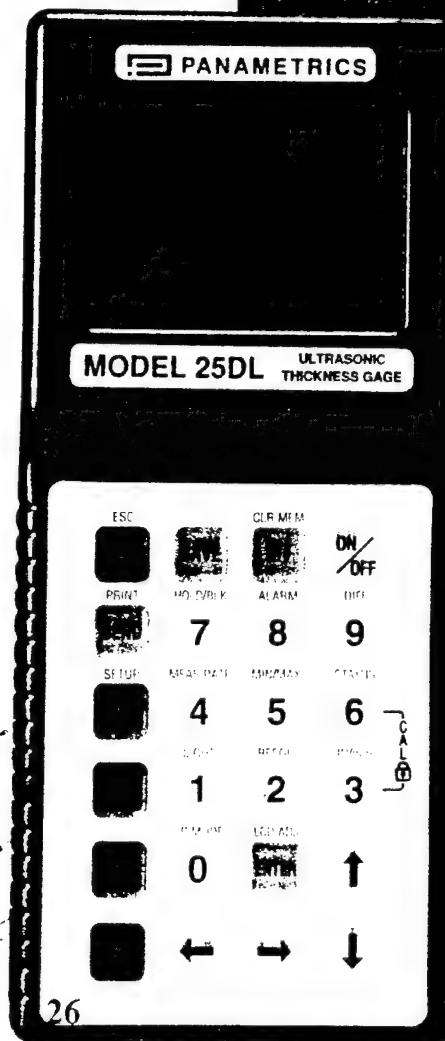
MEASUREMENT MODES:
Mode 1: Time interval between excitation pulse and first backwall echo. Using contact transducers.

Mode 2: Time interval between the first interface echo after the excitation pulse and the first backwall echo. Using delay line or immersion transducers.

Mode 3: Time interval between successive backwall echoes following the first interface echo after the excitation pulse. Using delay line or immersion transducers.

THICKNESS MEASUREMENT RANGE:
Steel: 0.006 - 20 inches (0.15 - 500mm).*
Plastic: 0.003 - 2 inches (0.08 - 50mm).*
Extended thickness ranges are possible using custom setups.

MATERIAL VELOCITY RANGE:
0.03000 - 0.55110 inch/µS
(0.7620 - 13.9979mm/µS).

RESOLUTION, keypad selectable:
LOW: 0.01"   0.1mm
STANDARD: 0.001"   0.01mm
HIGH: 0.0001"   0.001mm

MEASUREMENT RATE, keypad selectable:
1. 2. 5. or 10 measurements per second.

BATTERY:
6V Rechargeable NiCad battery pack.
Optional replaceable alkaline "A" cells.

BATTERY LIFE:
30 hrs nominal (normal operation). Nicad.
Optional alkaline "A" cells approximately 70 hours.

LOW BATTERY INDICATOR:
Active display shows percentage of remaining battery life. Symbol blinks when voltage becomes low.

BATTERY CHARGE TIME:
7 hours using provided charger.

CHARGER:
External wall plug-in charger/AC Adapter for 100/115/230 VAC inputs.

AUTO POWER OFF:
Unit automatically shuts off 6 to 18 minutes (selectable) after last measurement or keystroke. Also when voltage is too low.

RECEIVER BANDWIDTH:
2 - 30MHz (-3dB).

OPERATING TEMPERATURE:
-10° C to +50°C.

KEYPAD:
Sealed color coded keypad with tactile and audible feedback.

SIZE:
L7.70 x W3.39 x D1.70"
L195.6 x W86.2 x D66.9mm.
Depth at display is slightly larger.

WEIGHT:
1 lbs. 3oz. (0.59Kg).

THICKNESS DISPLAY:
5-Digit LCD with Backlight. 0.5" (12.7mm) numerals. Viewable area 2.2" x 1.5" (56.3 x 38.4mm).

BACKLIGHT, keypad selectable:
Electroluminescent backlit display. Contrast keypad adjustable.

DISPLAY MIN/MAX MODE, keypad selectable:
Displays current thickness, minimum thickness, or maximum thickness depending on setting.

DISPLAY HOLD/BLANK, keypad selectable:
Display blanks after last reading or holds reading.

ALARM MODE, keypad selectable:
Programmable Hi-Low alarm setpoints with audible and visual indicators.

DIFFERENTIAL MODE, keypad selectable:
Displays thickness difference between actual measurement and preset reference value.

APPLICATION AUTO-RECALL:
The 25DL automatically adjusts internal parameters and zero offset for a wide variety of transducers.

STORED STANDARD SETUPS:
15 stored transducer setups to allow fast, easy calibration for Panametrics standard transducers.

STORED CUSTOM SETUPS:
Up to 16 stored custom transducer setups for best performance in special applications.

PC SCOPE:
Allows measurement waveform with gates and thickness readings to be viewed live on a computer.

METRIC/ENGLISH UNITS, keypad selectable:
Allows instant conversion between English and metric units.

MULTI-LANGUAGE DISPLAY:
Keypad selectable display languages. Included are English, French, German, and Spanish.

OTHER STANDARD 25DL FEATURES: Calibration Lock Mode, Internal Diagnostic Test Mode.

Internal Datalogger

DATALOGGER AND RS-232:
The 25DL will identify, store, recall, clear, and transmit thickness readings and gage setup information via the full duplex RS-232 Serial Port.

MAX. # OF STORED VALUES:
Over 5,000 thickness readings.

STORED DATA DOCUMENTATION:
Each saved thickness reading is fully documented with measurement status flags and a setup number which identifies parameters such as velocity, transducer, etc.

IDENTIFICATION CODES:
10 character alphanumeric Identification Code system identifies or locates stored data.

AUTO INCREMENTING:
Datalogger automatically advances to the next alphanumeric identification code, starting at the right most character.

ON-BOARD STATISTICS CALCULATOR:
Permits statistical reporting directly to Serial Printer.

BAUD RATE, keypad selectable:
1200, 2400. 4800. or 9600.

WORD LENGTH, keypad selectable:
7 OR 8 bits.

STOP BITS, keypad selectable:
Even, odd, or none.

Ordering Information

Model 25DL Digital Ultrasonic Multi-Mode Thickness Gage, AC or Battery Operation, 50-60Hz, with Internal Alphanumeric Datalogger. Including:

Charger/Adapter (100, 115, 230VAC)

Transducer Cable

Test Block

Couplant

RS-232 I/O Cable

Carrying Case

Instruction Manual

Two Year Limited Warranty

Optional Accessories

25DL/SPC Protective Pouch with Neck Strap

DLIP/25DL Interface Program

25DL/EW Extended Limited Warranty, 3rd Year

DL/KX   Standard Dot Matrix Printer, 80 column, 115 VAC only

25SM   PC Scope

26PR   Portable Printer, 80 column, Battery or 115 VAC

2214E†   5-Step Test Block, 1018 steel, English Units: .100", .200", .300", .400", .500"

2213E†   5-Step Test Block, Aluminum, English Units: .100", .200", .300", .400", .500"

26DL/OCC Heavy Duty Shipping Case

†Test Blocks are available in metric units.

Please contact Panametrics for other accessories available with the model 25DL.

PANAMETRICS

221 Crescent Street
Waltham, MA 02154 USA

(617) 899-2719
Toll Free USA (800) 225-8330
Fax (617) 899-1552

*Thickness range depends on material, transducer, surface condition, temperature, and SETUP selected.
All specifications are subject to change for product improvement without notice.

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